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The present set of experiments investigated the effect on fixed-interval performance of varying feeder duration both between and within sessions. In Exp. 1 only one feeder duration was presented within a session and feeder duration was varied over blocks of sessions. There was no effect of feeder duration on fixed-interval performance in Exp. 1. Phase 1 of Exp. 2 investigated the effect of randomly presenting one of two feeder durations at the termination of each fixed-interval, for several values of the shorter duration. The mean time to the first response was found to be directly related to the feeder duration which initiated the fixed-interval. Phase 2 of Exp. 2 explored the effects of separating successive fixed-intervals in time, over a range of time-out values. In phase 2 of Exp. 2 the mean time to the first response was found to decrease following both the long and short feeder durations as the value of the time-out was increased. Several mechanisms which depend on the intermixing in time of two or more feeder durations are discussed as possible explanations for the differential responding observed to follow long versus short feeder durations.

THE EFFECT OF FEEDER DURATION ON FIXED-INTERVAL PERFORMANCE: CONTEXT DEPENDENCIES

by

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Approved by

Thesis Adviser

APPROVAL PAGE

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CHAPTER I

INTRODUCTION

A fixed-interval schedule of reinforcement provides that the first response after a fixed period of time has elapsed be reinforced. The task of providing various feeder durations at the termination of a fixed-interval may be accomplished in several ways. One possibility is to randomly present one of several feeder durations at the end of each interval without accompanying exteroceptive stimuli which would predict the duration to be presented. A second possibility is to follow the procedure of randomly presenting one of several feeder durations at the conclusion of each interval with the addition of differential stimuli which predict the duration to be presented. Such an arrangement is designated as a multiple schedule of reinforcement. Both of these procedures require that feeder duration be varied within each experimental session. Still another possibility is to use a parametric variation of the multiple procedure and provide only one duration within a single session and vary the duration of food presentation over blocks of sessions. The

addition of exteroceptive stimuli which would predict the various feeder durations seems unnecessary under this procedure since, with the possible exception of the initial portion of the first session, the duration can be predicted with certainty.

The presentation of a reinforcing event may influence performance in a number of ways. One way in which the reinforcing event may affect behavior is by exerting a direct strengthening effect on preceding responses. For example, the rate at which a response occurs may be increased by increasing the rate of reinforcement. If two or more discriminative stimuli are incorporated in the procedure, responses which occur in the presence of one stimulus may be strengthened while responses made in the presence of alternate stimuli are extinguished. In addition to such direct strengthening effects, a food reinforcer may serve as a discriminative stimulus itself. On fixed-interval schedules, for example, the reinforcer signals a period of non-reinforcement. This function of the reinforcing event is most properly designated as a discriminative after-effect since it exerts control over behavior which follows it in time. The discriminative and strengthening functions of the

reinforcing event must both be considered since it is often difficult to assess the effects of one independently of the effects of the other.

EXPERIMENT 1

A two-state analysis of fixed-interval performance conceives of the schedule as two time periods, a latency to the first response and the interval between the termination of this latency and the next reinforcement. Responses typically occur at a relatively high and constant rate during the latter time period. When feeder duration is held constant the mean time to the first response increases linearly with fixed-interval duration, approximating one-half the interval duration over a range of schedule values (Schneider, 1969; Shull, 1971).

Powell (1969) has reported that latency to the first response on fixed-ratio schedules is dependent on feeder duration. Powell investigated the effect of two different feeder durations upon responding under a range of fixed-ratio requirements. The feeder durations and their associated exteroceptive stimuli were varied both between and within sessions. Either the durations were presented during alternate sessions or one duration was presented during the

first half of the experimental session while the other duration was presented during the last half of the experimental session. In all cases Powell found that the time to the first response was shorter when the longer feeder duration was in effect. When a measure of response rate was calculated which did not include the time to the first response, Powell found no systematic relationship between feeder duration and "running rate". This finding suggests that time to the first response on fixed-interval schedules may also depend on specific parameters of the reinforcing event. Experiment 1 was conducted to determine the relationship between feeder duration and the time to the first response on fixed-interval schedules of food presentation when feeder duration is varied over blocks of sessions.

METHOD

Subjects

Three Silver King pigeons were maintained at approximately 80% of their free-feeding weights throughout the study. All subjects had had previous experience with fixed-interval schedules of reinforcement.

Apparatus

The experimental space was a converted ice chest. Three circular, translucent pigeon keys were mounted on an inserted metal wall. Only the center key was used in this experiment. A rectangular opening directly below the center key provided access to mixed grain which was illuminated by a white light only during reinforcement. The mixed grain was presented by means of food hopper mounted behind the wall. Also mounted behind the wall were lights which permitted transillumination of the center key. A peck on the illuminated key produced a feedback click from a relay mounted behind the front wall. The response key was illuminated with a blue light during each fixed-interval. During reinforcement the key light was extinguished and responses had no programmed consequences.

Programming and recording were accomplished through the use of standard electro-mechanical equipment. Responses were recorded on digital counters, while the total session time and cummulative time to the first response were accumulated on running time meters. A printout counter provided a record of the time to the first response in each interval. In addition a cummulative recorder provided daily records of the patterning of responses throughout the session.

Procedure

A fixed-interval two-min schedule programmed grain reinforcement. That is, the first response after two min had elapsed occasioned reinforcement. In Exp. 1 feeder durations were varied between blocks of sessions. A particular feeder duration was in effect for 15-39 consecutive sessions. The effects of the following durations were investigated: 0.5, 1, 2, 4, and 8 sec. The subject received 40 reinforcements per session except when the feeder duration in effect was 8 sec. Under this condition the subjects received only 20 reinforcements per session.

The birds were first trained on the 4 sec condition and then shifted to the 8 sec duration. Following the 8 sec condition the feeder duration was decreased over blocks of sessions until a duration was reached that would not maintain responding. Sessions were conducted daily and were automatically terminated after the last reinforcement. Data were not recorded during the first interval.

RESULTS and DISCUSSION

Figure 1 presents the mean latency to the first response for each bird averaged over the last five sessions of each feeder duration. In addition, redetermination points have

been plotted for the 4 sec condition. Points are not plotted for feeder durations which failed to maintain performance. The mean time to the first response approximated one-half the interval duration for B-2 regardless of feeder duration except at the shortest durations (not plotted), where performance disintegrated. This was also true for B-3 except for a slight increase at the 8 sec duration. For B-1 the mean latency to the first response was consistently longer than half the interval duration but even for this bird there was little effect of feeder duration. There seems then to have been no systematic effect of feeder duration on the latency to the first response when duration was varied between blocks of sessions.

Figure 2 presents two response rate measures for each subject taken over all feeder durations investigated in Exp. 1. Redetermination points have been plotted for the 4 sec condition and again, points are not plotted for durations which failed to maintain performance. The filled circles represent running rate. This measure of response rate excludes the time to the first response from the calculation and is obtained by dividing the total number of responses by the total session time (which excludes reinforcement time) minus the total pause time. When running rate is

Figure 1. The mean latency to the first response for each bird averaged over the last five sessions of each feeder duration. The attached symbols are redetermination points for the 4 sec feeder duration.

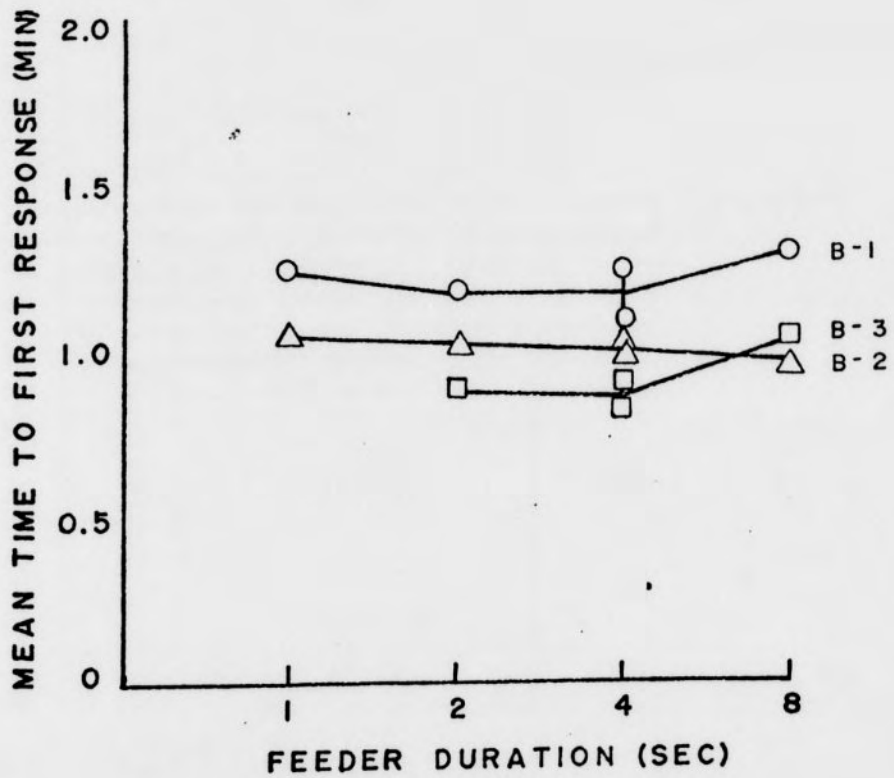
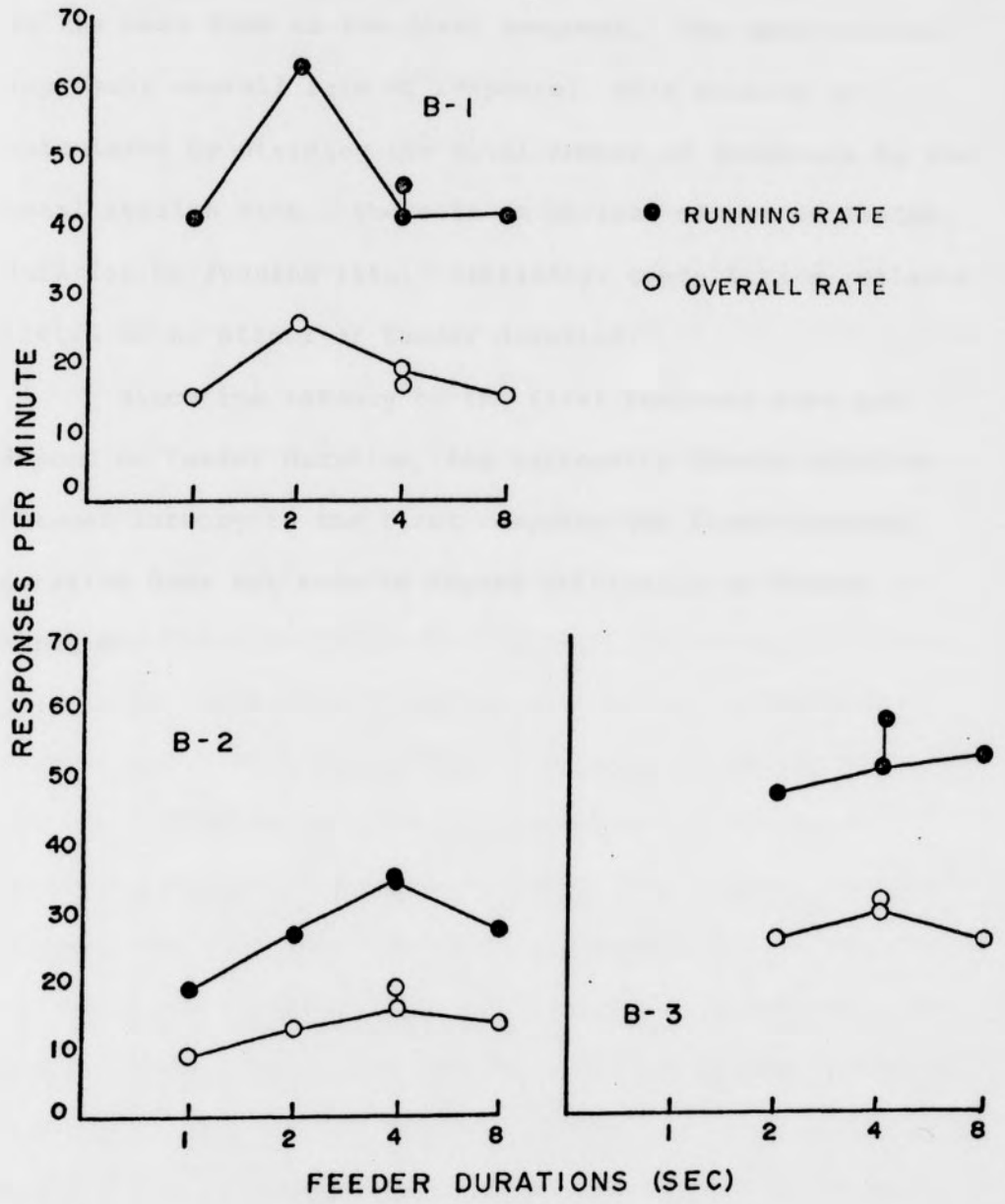

MEAN TIME TO FIRST RESPONSE (MIN)
2.0
1.5
1.0
0.5
0
B-1
B-3
B-2
1
2
4
8
FEEDER DURATION (SEC)

Figure 2. Response rate measures for each subject taken over all feeder durations investigated in Exp. 1. The filled circles represent running rate. The open circles represent overall response rate. The attached symbols are redetermination points.


B-1
B-2
B-3
RUNNING RATE
OVERALL RATE
RESPONSES PER MINUTE
FEEDER DURATIONS (SEC)
0
10
20
30
40
50
60
70
1
2
4
8

constant any change in overall rate must be due to a change in the mean time to the first response. The open circles represent overall rate of response. This measure is calculated by dividing the total number of responses by the total session time. There is no obvious effect of feeder duration on running rate. Similarly, overall rate reflects little or no effect of feeder duration.

Since the latency to the first response does not depend on feeder duration, the increasing linear relation between latency to the first response and fixed-interval duration does not seem to depend critically on feeder duration.

CHAPTER II

EXPERIMENT 2

Staddon (1970a) investigated the effects of varying feeder duration within fixed-interval sessions. He randomly presented one of five durations at the termination of each interval. No differential stimuli were correlated with the different feeder durations. Staddon found time to the first response to be directly related to the feeder duration initiating each interval. That is, latencies to the first response tended to be longer following the longer feeder durations than following the shorter durations. Staddon attributed the difference in pausing to the pause-producing after-effects of food presentation on fixed-interval schedules. He proposed that this effect increases in magnitude with increases in the duration of the reinforcing event and suggested that the effect was absolute rather than relative. This view must be modified in some manner in order to account for the data of Exp. 1. When only one duration was presented within an experimental session no systematic differences in latency to the first response were

observed as would be expected if feeder durations were acting to differentially inhibit responding in the subsequent interval. Thus, the data of Exp. 1 raise the question of why differences in latency to the first response are found when more than one duration is presented within a session and such differences are not found when only one duration is presented within a session.

There are at least two different patterns of behavior which would result in different mean pause durations following different feeder durations. First, differential pausing could be the result of a general shortening of latencies following the shorter feeder durations. A second possibility is that the mean latency to the first response is shorter after shorter durations than longer durations, not because of a general shift in the distribution of latencies, but because of the occurrence of a significant number of "run-throughs". These run-throughs would be the result of occasional intervals on which the animal "misses" the shorter feeder duration and continues to respond on into the next interval. If this were the case, a shorter mean latency might be obtained by averaging post-reinforcement pauses of typical length with these much shorter "post-miss" pauses.

To investigate this possibility feeder duration was varied within each session of Exp. 2. Distributions of latencies to the first response were obtained and constructed separately for intervals initiated by a short feeder duration and intervals initiated by a longer duration. These distributions were then inspected for bimodality.

If the differential pausing following various feeder durations observed by Staddon does not reflect a bimodal distribution of latencies then several additional accounts, in terms of a general effect of the prior feeder duration, must be considered as possible explanations of both Staddon's data and the data of Exp. 1. The first of these is an account in terms of frustration theory. As proposed by Amsel (1958, 1967) frustration theory involves three general factors. First, frustration is held to be a motivational state which produces an increment in general drive. Secondly, frustration produces "directional" effects (e.g. an avoidant response tendency) which are the result of frustration specific stimuli. The third factor which Amsel proposes is a secondary or "learned" form of the primary frustration reaction. This factor is modeled after Hull's fractional anticipatory goal response mechanism. The classic

procedure employed to evoke the frustration reaction involves the use of a double runway which has one goal box mid-way along its length and a second goal box at its end. During pretraining rats are rewarded in both the first and second goal box. During testing reward is either omitted or reduced in magnitude in the first goal box, while the reward in the final goal box is left unchanged. It is proposed that after a number of frustrative experiences in the goal box, resulting from non-reward or reductions in the amount or immediacy of reward, anticipatory frustration responses will begin to occur in the alley-way. It is assumed that frustration is an aversive motivational condition and that avoidant response tendencies will, through the process of classical conditioning, become associated with frustration produced stimuli. However, as approach tendencies are usually stronger, running speeds will increase as a result of the attachment of approach responses to frustration stimuli. The magnitude of the frustration effect is determined by a number of factors such as amount of reward in pretraining, similarity of the goal box on non-reinforced trials to the goal box on reinforced trials, and the degree of reduction in amount or immediacy of reward.

The theory predicts Staddon's (1970a) data in the following way. If the four shortest of the five feeder durations are viewed as reductions in the amount of reward relative to the fifth and longest feeder duration, then each of the shorter durations should evoke the primary frustration reaction. The magnitude of the frustration effect would here depend upon the degree of reduction in amount of reward involved. Thus, Staddon's finding that response rate increased as feeder durations were decreased accords with the theoretical predictions of frustration theory. In Exp. 1 of the present research the feeder duration was constant within each session for a number of consecutive sessions. Since the feeder duration presented always corresponded with the duration to which the subject was accustomed to receiving there was, in this sense, no reduction in amount of reward. Thus, the primary frustration reaction was never evoked and these data also accord with the theoretical predictions of frustration theory.

A viable alternative to frustration theory has been proposed by Staddon (1970b). The reinforcing event on fixed-interval schedules reliably signals a period of non-reinforcement. As a direct consequence of this fact, times

early in the interval are consistently paired with non-reinforcement which results in a pause following each reinforcer presentation. In this sense, the reinforcing event exerts inhibitory temporal control over responding in the subsequent interval. The view that the reinforcing event acts as a temporally controlling stimulus whose effects are apparently inhibitory has been advanced by Staddon in connection with a number of experimental findings (Staddon and Innis, 1966; Staddon and Innis, 1969; Staddon, 1972). When reinforcement is occasionally completely omitted on fixed-interval schedules responding continues at a high rate until reinforcement is once again delivered. This naturally results in a greatly increased rate in those intervals not initiated by reinforcement. Rather than appealing to an excitatory process to explain this rate increase, as does frustration theory, Staddon views the increase as the result of the removal of a stimulus which has an inhibitory after-effect. Staddon and Innis (1969) have also reported rate increases in intervals initiated by a brief stimulus presented in lieu of reinforcement. The magnitude of these rate increases, however, was not as great as those observed under the complete omission procedure (no stimulus change). Since

running rate is by and large constant regardless of the event which initiates the fixed-interval all of the rate changes being referred to here may be attributed to changes in the mean time to the first response. Thus, the somewhat smaller rate increases following a brief stimulus as compared to no stimulus change may be taken as evidence that the brief stimuli presented in lieu of reinforcement also exert inhibitory temporal control over responding in the subsequent interval. The pauses produced by these brief stimuli, however, are much shorter than those produced by a reinforcer presentation. This is a problem, however, since both events predict a constant period of non-reinforcement. It is necessary to introduce some factor in addition to predictiveness in order to account for the shorter pauses generated by the brief stimuli. Staddon has proposed that the shorter pauses are an instance of stimulus generalization and Kello (1972) has reported data which support this position. Kello used an omission procedure in which the stimulus presented in lieu of reinforcement was varied with respect to the number of dimensions presented. For example, there was either no stimulus change, a blackout, or a blackout plus the magazine light. Kello found that as the

number of dimensions presented was increased there was a corresponding increase in the mean time to the first response. Thus, it appears that stimuli presented in lieu of reinforcement also exert inhibitory temporal control, with the magnitude of the pause-producing effect depending upon the similarity of the substituted stimulus to the reinforcing event.

Many behavioral effects may be understood in terms of predictiveness and stimulus generalization. Other data have been reported, however, which can not be understood without the introduction of additional mechanisms. In an experiment on reinforcement omission Staddon and Innis (1969) found that as the duration of a blackout presented in lieu of reinforcement was increased longer pauses were generated following the blackout. Hence, a long blackout is apparently more inhibitory than a short blackout. Staddon (1970a) has reported a similar relationship between feeder duration and the mean time to the first response. Neither predictiveness nor the process of stimulus generalization is capable of accounting for these findings. The behavioral effects which result from varying feeder duration within sessions as well as those which result from varying blackout

duration may be understood, however, if it is assumed that in addition to the control which results from predictiveness the duration of the stimulus has discriminative effects which can not be attributed to predictive properties. This is not to say that predictiveness becomes less important but rather that the effect of a predictive stimulus is modulated by the duration of that stimulus. While an account which includes the property of stimulus duration is adequate for the differential pausing reported by Staddon (1970a) and Staddon and Innis (1969) it can not deal with the data of Exp. 1. If different feeder durations have absolute differential after-effects these should have resulted in longer pauses following the longer feeder durations in Exp. 1. Since this result was not observed it seems necessary to conclude either that stimuli of various durations have no differential after-effects or that such effects are context dependent i.e. that stimuli of various durations will result in differential after-effects only when several feeder durations (or a blackout and a feeder duration) are relatively closely intermixed in time. If the former conclusion is adopted there is no ready explanation for the difference between the findings of the

present Exp. 1 and those reported by Staddon (1970a). If, on the other hand, the latter conclusion is adopted several possible explanations of Staddon's findings which are consistent with the data of Exp. 1 may be considered.

Staddon (1972) has offered an interpretation of the differential pausing he has reported which takes into consideration the "memory capacity" of the subject. Staddon has proposed that highly salient events such as food delivery may easily "overshadow" a brief blackout. That is, after several seconds have elapsed within the fixed-interval the subject may "remember" only the presentation of the reinforcer, the more salient of the two events. If this is indeed the case, it would seem to the subject that a great deal of time had elapsed since the termination of the last fixed-interval. This proposal is capable of explaining the short pauses Staddon and Innis (1969) observed following very brief blackouts. Staddon and Innis also found that with a blackout duration of 32 sec the mean pause durations were the same whether the interval was initiated by the termination of a reinforcer or a blackout. Staddon (1972) has suggested that while a reinforcer may easily overshadow a brief blackout, overshadowing becomes less probable as the

blackout is increased in duration. This reasoning can be easily extended to experiments in which the duration of the reinforcing event, rather than a blackout, is varied within sessions. The presentation of a short feeder duration may be overshadowed by the earlier presentation of a longer feeder duration. Thus, the overshadowing hypothesis is an adequate explanation for Staddon's finding that the mean time to the first response was greater following the longer feeder durations than following the shorter durations. The data of Exp. 1 are not obviously inconsistent with this hypothesis since overshadowing refers to a mechanism which generates context-dependent effects.

An account in terms of discriminative after-effects is attractive in that it avoids some problems which have been raised for frustration theory in general and is, on balance, a more parsimonious account. For example, Kello's (1972) findings are in direct opposition to the predictions of frustration theory. Jenson and Fallon (1973) have also reported data on both reinforcer omission and reinforcer duration which are best explained in terms of the inhibitory after-effects of the reinforcing event.

Another possible explanation is that when two or more feeder durations are presented within a single session differential pausing results from a relative comparison on the part of the organism between the duration just received and the average duration. On a mixed schedule the duration to be presented is unpredictable and only the average duration can be predicted. For example, if equal numbers of 2 sec and 8 sec feeder durations were presented unpredictably within a session the average duration for each fixed-interval would be 5 sec. It can be seen that when a fixed-interval is initiated by an 8 sec feeder this average duration will be smaller than the duration just received. Conversely, during those intervals initiated by the 2 sec feeder the 5 sec average will be larger than that just received. Thus, a 2 sec feeder duration predicts a relative improvement in conditions while the 8 sec feeder duration predicts a relative worsening of conditions. This account should not be confused with the phenomenon of behavioral contrast (Reynolds, 1961). The view being presented here is much more similar to the reinforcement--context--contrast phenomenon which has been investigated by Crespi, Zeaman, and others (see Kling and Riggs, 1971 for a complete summary of their findings).

Increases in the rate of response which reflect decreases in the mean time to the first response in the present account are not held to be the result of interactions between fixed-interval components. Rather, the increases in response rates are held to be the result of a shift from a short feeder duration to a relatively longer average duration.

Regardless of which of the above explanations one chooses to adopt consideration of Staddon's (1970a) data in conjunction with the data of Exp. 1 renders obvious the fact that the intermixing in time of several feeder durations is an important factor in obtaining differential pausing. Thus, when fixed-intervals are terminated by different feeder durations within a session the separation of successive fixed-intervals in time would seem to be an important variable. Within the context of experiments designed to support the after-effects view Staddon and Innis (1969) have reported that as the duration of a time-out presented in lieu of reinforcement was increased, the omission effect was systematically attenuated and eventually eliminated. In experiments conducted in the runway setting and designed to evaluate frustration theory a similar manipulation, referred to as detention time, has been employed. Detention time is

the amount of time the subject is forced to remain in an empty goal box before being allowed to enter the alley-way. This manipulation has been found to reduce or eliminate the frustrative effect of non-reward (McKinnon and Amsel, 1964). To the extent that the degree of rate enhancement is related to the degree of reward reduction (Bower, 1962) such temporal factors may also be important with respect to feeder duration effects. Thus, there is ample reason to suspect that the separation of successive fixed-intervals (or runway trials) in time is an important variable and, in addition, is a variable that is apparently important to consider for both frustration theory and an account in terms of inhibitory after-effects as well.

The separation of successive fixed-intervals in time was investigated parametrically in the second phase of Exp. 2 by interpolating a time-out after every reinforcement. Two feeder durations were also employed in this phase of Exp. 2. The duration of the time-out was systematically increased to a value which significantly reduced or eliminated differential pausing.

Thus, the first phase of the present experiment investigated the effect of randomly presenting one of two feeder

durations at the termination of each fixed-interval, for several values of the shorter duration. In addition, the second phase of the present experiment explored the effects of separating successive fixed-intervals in time, over a range of time-out values. Detailed examinations of the effects of these manipulations on the latency distributions were performed.

METHOD

Subjects

The subjects of Exp. 1 served.

Apparatus

The apparatus was the same as that employed in Exp. 1 during the first phase of Exp. 2. Phase two of Exp. 2 was conducted in a different experimental space, a standard Lehigh Valley pigeon chamber. The chamber was equipped with two response keys but only the right key was used in Exp. 2. Programming and recording were accomplished as described in Exp. 1.

Procedure: Phase 1

The procedure for this phase of Exp. 2 was basically the same as that employed in Exp. 1, that is, responding was reinforced with grain on a fixed-interval two-min schedule. The procedures of Exp. 2 differed from that of Exp. 1 in that

in both phases of Exp. 2 responding on the fixed-interval produced either an 8 sec feeder duration or a shorter duration. There was no exteroceptive stimulus signalling which duration would occur and each feeder duration occurred with an equal probability within each session. The value of the shorter duration was either 0.5, 1, or 2 sec. A particular shorter feeder duration was paired with the 8 sec duration for at least five consecutive sessions. The subjects received 40 reinforcements per session in both phases of Exp. 2. Latencies following the 8 sec feeder duration were recorded separately from latencies following the shorter duration.

Procedure: Phase 2

Phase 2 differed from phase 1 only in that a time-out was scheduled between each termination of the reinforcing event and the beginning of the next fixed-interval. The two feeder durations investigated in phase 2 were 1 and 8 sec. The duration of the time-out was varied over blocks of sessions and was constant within a given session. The values investigated were: 5, 10, 20, 60, and 120 sec. The length of the experimental sessions necessarily increased as the value of the time-out was increased. Each time-out was in effect for from 10 to 35 consecutive sessions.

RESULTS

Phase 1

Figure 3 presents for each subject the mean latency to the first response averaged over the last 5 sessions of each condition. The open symbols represent latencies from intervals following the 8 sec feeder duration. The filled symbols represent latencies following the shorter durations. The isolated points present latency data from sessions where only the 8 sec feeder duration was presented. In every case the mean latency to the first response was longer following the 8 sec duration than following the shorter duration. The difference between these means tended to increase as the value of the shorter duration was decreased. This result differs from the data of Exp. 1 where there was little effect of feeder duration on the latency to the first response. As mentioned earlier, it is possible that the different mean pause durations observed in Exp. 2 resulted from "run-throughs" following the shorter durations. To investigate this possibility the latency distributions were examined in more detail.

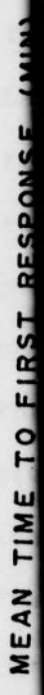
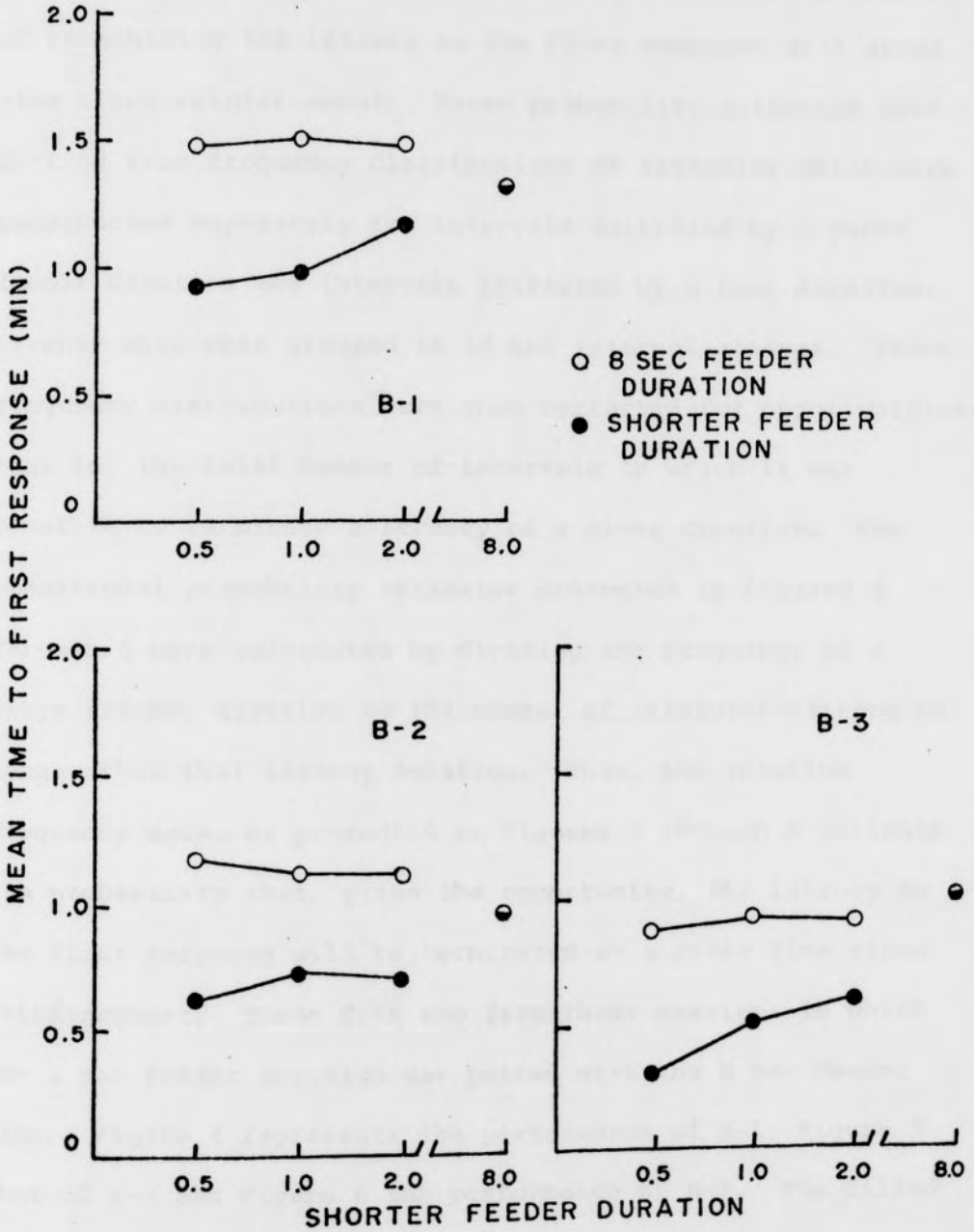


Figure 3. The mean latency to the first response for each subject averaged over the last 5 sessions of each condition. The open symbols represent latencies from intervals following the 8 sec feeder duration, the filled symbols latencies following the shorter durations. The isolated points are from sessions in which only the 8 sec feeder duration was presented.


2.0
1.5
1.0
0.5
0
MEAN TIME TO FIRST RESPONSE (MIN)
B-1
B-2
B-3
○ 8 SEC FEEDER DURATION
● SHORTER FEEDER DURATION
0.5
1.0
2.0
8.0
SHORTER FEEDER DURATION

Figures 4 through 6 estimate the conditional probability of terminating the latency to the first response at a given time since reinforcement. These probability estimates were derived from frequency distributions of latencies which were constructed separately for intervals initiated by a short feeder duration and intervals initiated by a long duration. Latency data were grouped in 12 sec interval-classes. These frequency distributions were then corrected for opportunities: that is, the total number of intervals in which it was possible to terminate a latency of a given duration. The conditional probability estimates presented in figures 4 through 6 were calculated by dividing the frequency of a given latency duration by the number of latencies as long or longer than that latency duration. Thus, the relative frequency measures presented in figures 4 through 6 estimate the probability that, given the opportunity, the latency to the first response will be terminated at a given time since reinforcement. These data are from those sessions in which the 2 sec feeder duration was paired with the 8 sec feeder time. Figure 4 represents the performance of B-1, Figure 5 that of B-2 and Figure 6 the performance of B-3. The filled circles represent the probability of terminating the latency

Figure 4. Probability of terminating the latency to the first response at some time since reinforcement, given the opportunity, after the 2 sec duration (filled circles) and after the 8 sec duration (filled triangles). The dashed curves with open symbols were obtained from latencies in Exp. 1 and are plotted here for comparison. This figure presents the performance of B-1.

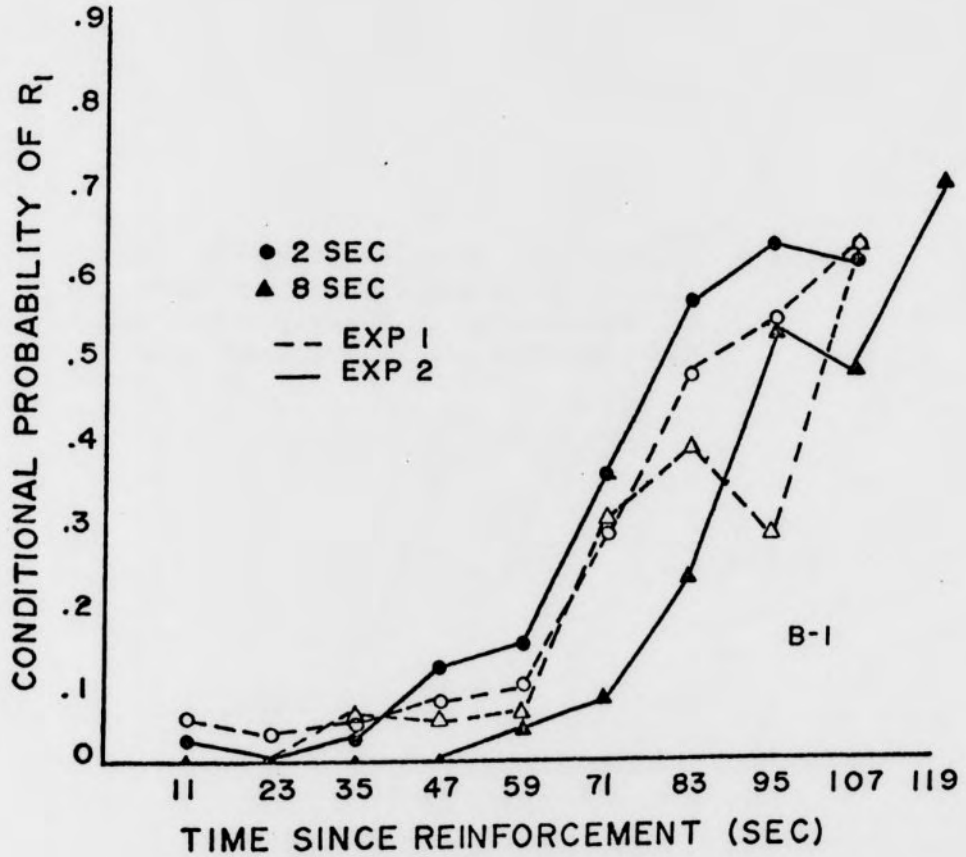

CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
● 2 SEC
▲ 8 SEC
-- EXP 1
— EXP 2
B-1
11
23
35
47
59
71
83
95
107
119
TIME SINCE REINFORCEMENT (SEC)

Figure 5. Probability of terminating the latency to the first response at some time since reinforcement, as described in Fig. 4, representing the performance of B-2.

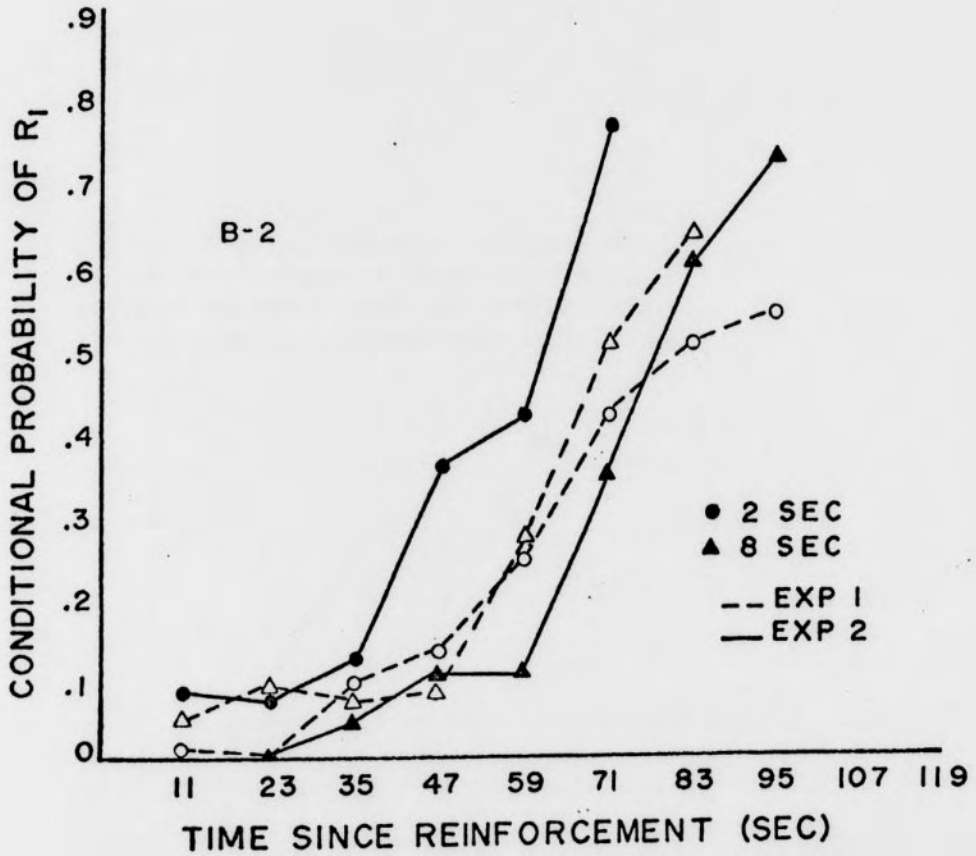
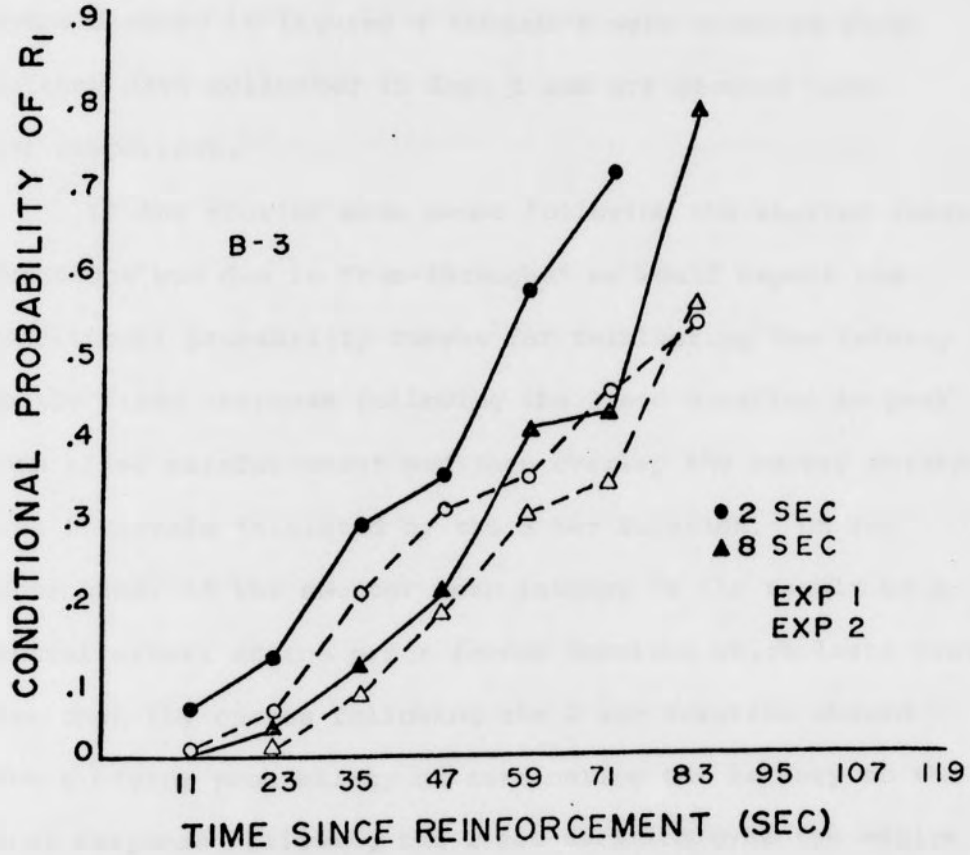

CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
B-2
● 2 SEC
▲ 8 SEC
-- EXP 1
— EXP 2
11
23
35
47
59
71
83
95
107
119
TIME SINCE REINFORCEMENT (SEC)

Figure 6. Probability of terminating the latency to the first response at some time since reinforcement, as described in Fig. 4. This figure represents the performance of B-3.


CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
B-3
● 2 SEC
▲ 8 SEC
EXP 1
EXP 2
11
23
35
47
59
71
83
95
107
119
TIME SINCE REINFORCEMENT (SEC)

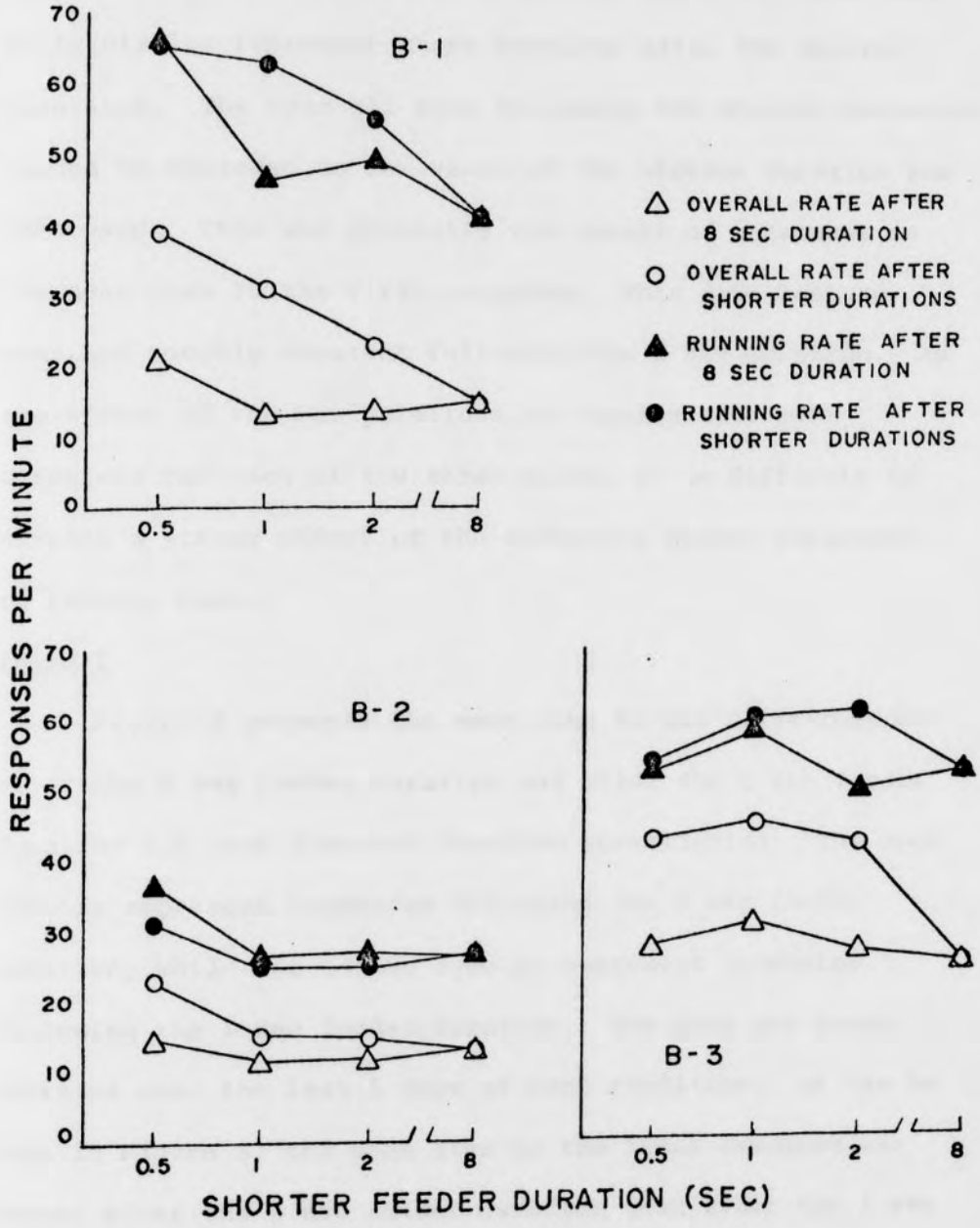
to the first response following the 2 sec duration while the filled triangles represent that probability following the 8 sec feeder duration. The solid curves were obtained from the latency data of Exp. 2. The dashed curves with open symbols shown in figures 4 through 6 were obtained from latency data collected in Exp. 1 and are plotted here for comparison.

If the shorter mean pause following the shorter feeder durations was due to "run-throughs" we would expect the conditional probability curves for terminating the latency to the first response following the 2 sec duration to peak soon after reinforcement and then overlap the curves obtained from intervals initiated by the 8 sec duration. On the other hand, if the shorter mean latency is the result of a general effect of the prior feeder duration which lasts over time then the curves following the 2 sec duration should show a higher probability of terminating the latency to the first response following the 2 sec duration over the entire interval. Figures 4 through 6 reveal that in Exp. 2 the probability of terminating a latency at a given time since reinforcement was higher over the whole interval after the 2 sec duration than after the 8 sec duration. When feeder durations shorter than 2 sec were paired with the 8 sec

duration, the probabilities following the shorter duration were even higher. The data from those sessions were similar in all other respects to the data presented in figures 4 through 6. The clear lack of bimodality across all combinations of short and long feeder durations supports the view that the shorter mean latencies following the shorter feeder durations resulted from a general effect of the prior feeder duration which lasts over time. Finally, the consistently higher probabilities of terminating the latency to the first response following the 2 sec feeder duration in Exp. 2 may be compared with the curves obtained from Exp. 1. In Exp. 1 there was little difference between the 2 and 8 sec curves with only B-3 showing a consistently higher probability of terminating the latency to the first response following the 2 sec duration.

Figure 7 presents response rate data for all subjects over all combinations of short and long feeder durations. In addition, the point labled "8" which was obtained from sessions of Exp. 1 in which only the 8 sec feeder duration was presented, is plotted for comparison. The filled symbols represent running rate while the open symbols represent over-all response rate. The triangles represent

Figure 7. Rate of response for all subjects over all combinations of short and long feeder durations investigated. The point labled "8" was obtained from sessions of Exp. 1 in which only the 8 sec feeder duration was presented and is plotted here for comparison. The filled symbols represent running rate while the open symbols represent overall response rate. Triangles represent rate measures from intervals following the 8 sec feeder, while circles represent rate measures from intervals following the shorter durations.

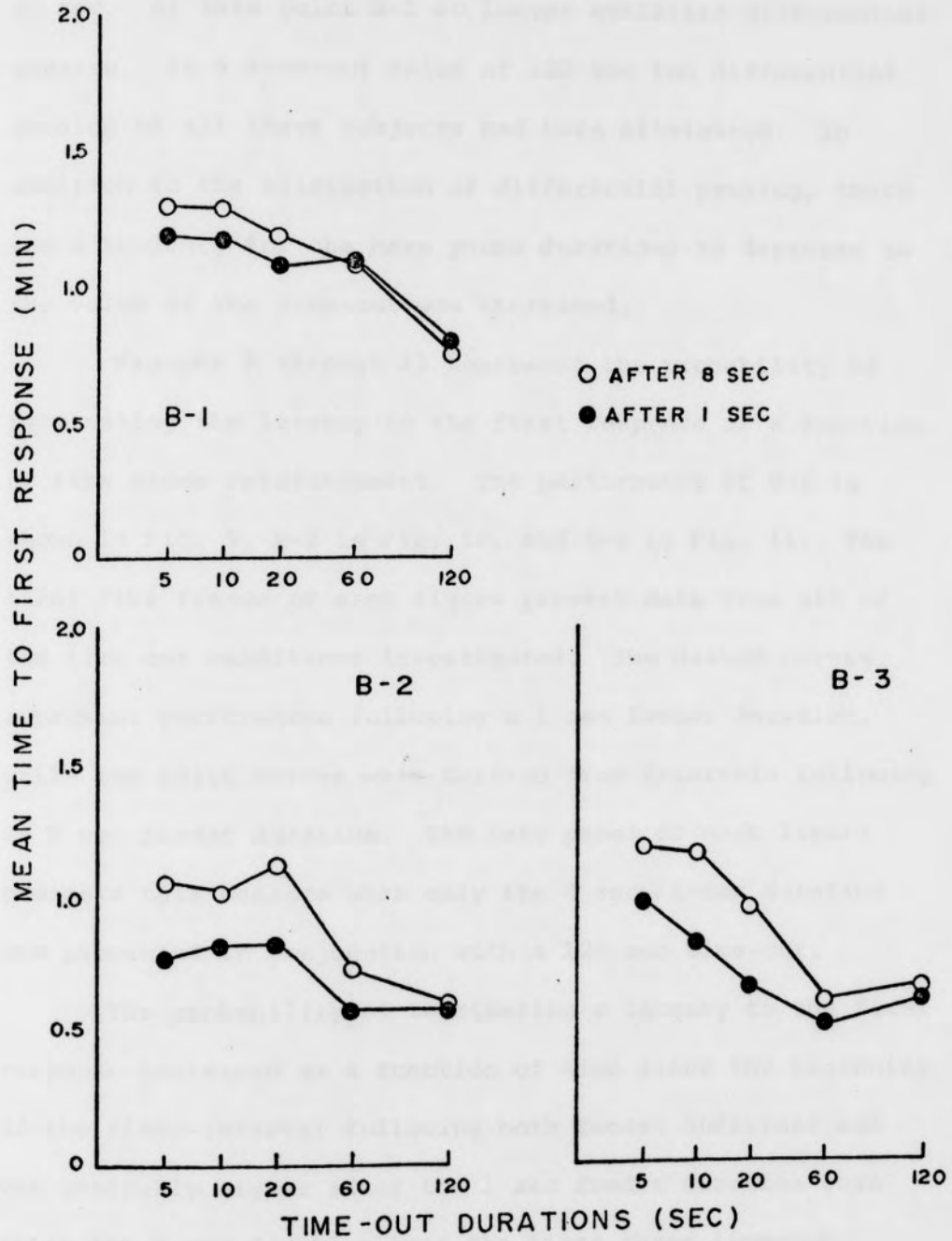

B-1
B-2
B-3
RESPONSES PER MINUTE
SHORTER FEEDER DURATION (SEC)
0
10
20
30
40
50
60
70
0.5
1
2
8
△ OVERALL RATE AFTER 8 SEC DURATION
○ OVERALL RATE AFTER SHORTER DURATIONS
▲ RUNNING RATE AFTER 8 SEC DURATION
● RUNNING RATE AFTER SHORTER DURATIONS

rate measures from intervals following the 8 sec duration, while circles represent those measures after the shorter durations. The over all rate following the shorter durations tended to decrease as the value of the shorter duration was increased. This was primarily the result of increases in the mean time to the first response. This rate measure remained roughly constant following the 8 sec duration. As the effect of the manipulations on running rate were different for each of the three birds, it is difficult to discern a strong effect of the different feeder durations on running rate.

Phase 2

Figure 8 presents the mean time to the first response after the 8 sec feeder duration and after the 1 sec feeder duration for each time-out duration investigated. The open symbols represent latencies following the 8 sec feeder duration, while the filled symbols represent latencies following the 1 sec feeder duration. The data are means averaged over the last 5 days of each condition. As can be seen in Figure 8, the mean time to the first response was longer after the 8 sec feeder duration than after the 1 sec feeder duration for all birds up to a time-out value of

Figure 8. The mean time to the first response following the 8 sec feeder duration (open symbols) and following the 1 sec feeder duration (filled symbols). The data are means averaged over the last 5 days of each condition.


MEAN TIME TO FIRST RESPONSE (MIN)
2.0
1.5
1.0
0.5
0
B-1
B-2
B-3
O AFTER 8 SEC
● AFTER 1 SEC
5
10
20
60
120
TIME-OUT DURATIONS (SEC)

60 sec. At this point B-1 no longer exhibited differential pausing. At a time-out value of 120 sec the differential pausing of all three subjects had been eliminated. In addition to the elimination of differential pausing, there was a tendency for the mean pause durations to decrease as the value of the time-out was increased.

Figures 9 through 11 represent the probability of terminating the latency to the first response as a function of time since reinforcement. The performance of B-1 is shown in Fig. 9, B-2 in Fig. 10, and B-3 in Fig. 11. The first five frames of each figure present data from all of the time out conditions investigated. The dashed curves represent performance following a 1 sec feeder duration, while the solid curves were derived from intervals following an 8 sec feeder duration. The last panel of each figure presents this measure when only the 4 sec feeder duration was presented in conjunction with a 120 sec time-out.

The probability of terminating a latency to the first response increased as a function of time since the beginning of the fixed-interval following both feeder durations and was generally higher after the 1 sec feeder duration than after the 8 sec duration over the first three time-out values. The curves overlap at the 60 sec time-out value for

Figure 9. Probability of terminating the latency to the first response as a function of time since reinforcement. The first 5 frames present data from all of the time-out conditions investigated, while the last panel of the figure presents data from sessions in which only a 4 sec feeder duration was presented in conjunction with a 120 sec time-out. The dashed curves represent performance following a 1 sec feeder duration, while the solid curves were derived from intervals following an 8 sec feeder. This figure presents the performance of subject B-1.

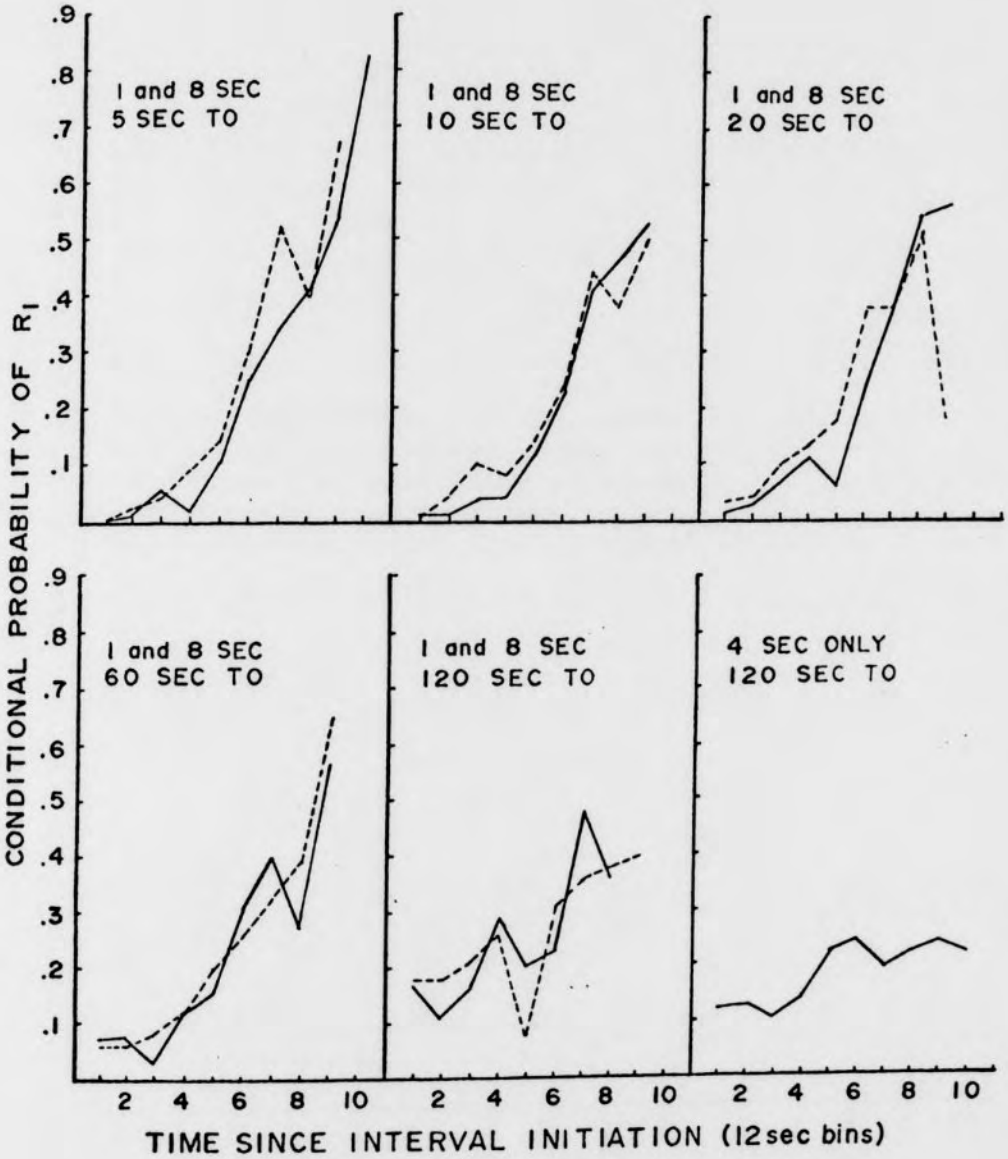
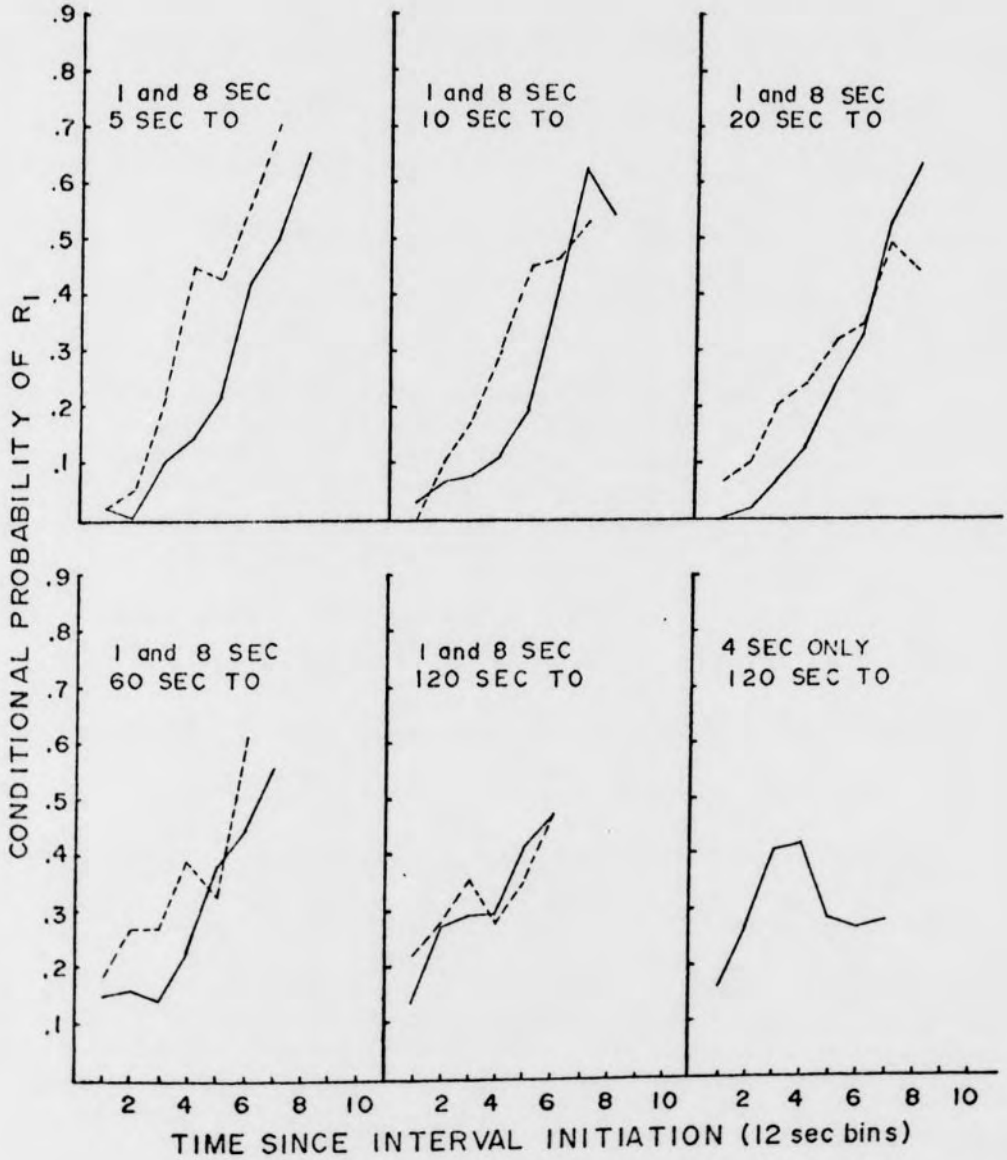

1 and 8 SEC
5 SEC TO
1 and 8 SEC
10 SEC TO
1 and 8 SEC
20 SEC TO
1 and 8 SEC
60 SEC TO
1 and 8 SEC
120 SEC TO
4 SEC ONLY
120 SEC TO
CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
2 4 6 8 10
TIME SINCE INTERVAL INITIATION (12sec bins)

Figure 10. Probability of terminating the latency to the first response as a function of time since reinforcement, as described in Fig. 9. This figure represents the performance of B-2.


1 and 8 SEC
5 SEC TO
1 and 8 SEC
10 SEC TO
1 and 8 SEC
20 SEC TO
1 and 8 SEC
60 SEC TO
1 and 8 SEC
120 SEC TO
4 SEC ONLY
120 SEC TO
CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
2 4 6 8 10
TIME SINCE INTERVAL INITIATION (12 sec bins)

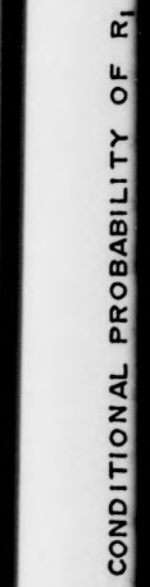
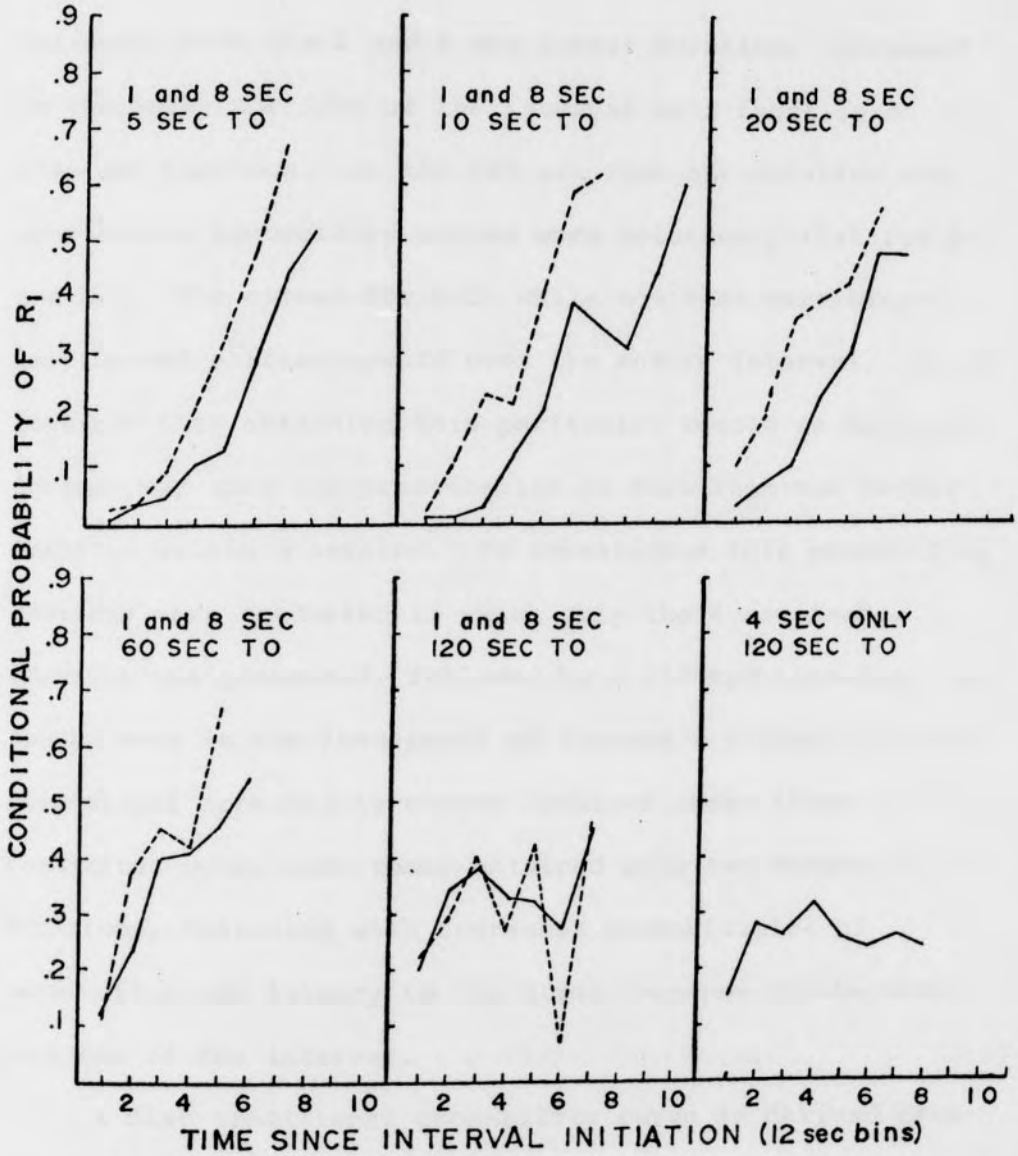


Figure 11. Probability of terminating the latency to the first response as a function of time since reinforcement, as described in Fig. 9. This figure represents the performance of subject B-3.


1 and 8 SEC
5 SEC TO
1 and 8 SEC
10 SEC TO
1 and 8 SEC
20 SEC TO
1 and 8 SEC
60 SEC TO
1 and 8 SEC
120 SEC TO
4 SEC ONLY
120 SEC TO
CONDITIONAL PROBABILITY OF R_1
.9
.8
.7
.6
.5
.4
.3
.2
.1
2 4 6 8 10
TIME SINCE INTERVAL INITIATION (12 sec bins)

B-1 and at the 120 sec value for all subjects. The probability of terminating the latency to the first response following both the 1 and 8 sec feeder durations increased in the early portions of the interval as a function of time-out duration. At the 120 sec time-out duration the conditional probability curves were relatively flat for B-1 and B-3. The curves for B-2, while not flat were overlapping and shifted upward over the entire interval. It is possible that obtaining this particular result is dependent in some way upon the presentation of more than one feeder duration within a session. To investigate this possibility sessions were conducted in which only the 4 sec feeder duration was presented, followed by a 120 sec time-out. As can be seen in the last panel of figures 9 through 11, the conditional probability curves obtained under these conditions were, like those obtained with two feeder durations, flattened with increased probabilities of terminating the latency to the first response in the early portions of the interval.

A flat conditional probability curve is derived from an exponential distribution of latencies to the first response which is negatively accelerated and decreasing.

Thus, the relatively flat curves of figures 9 through 11 may be taken to represent a large number of short latencies and hence a decrease in the mean time to the first response.

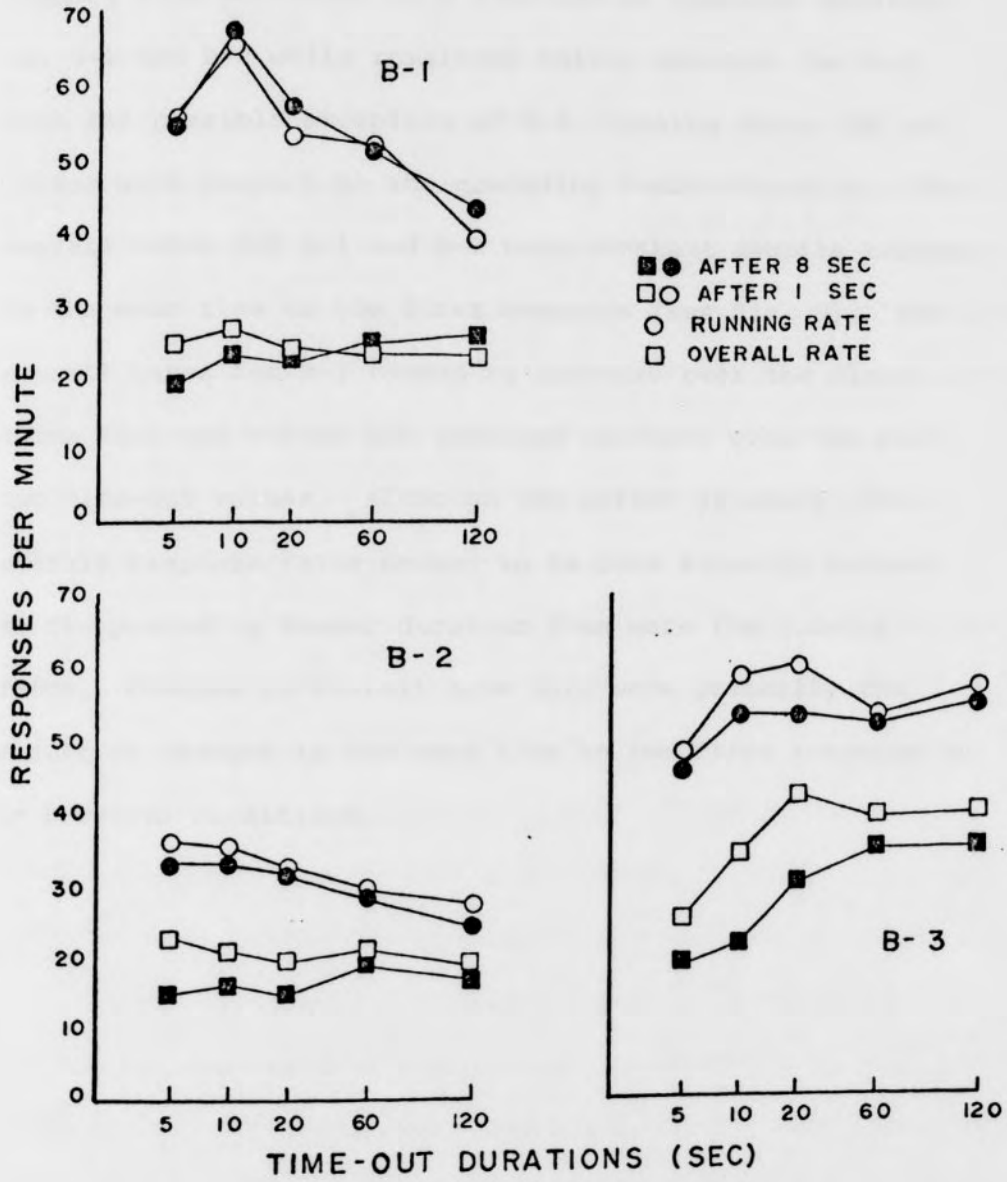
The gradual increase in the probability of terminating a latency to the first response which accompanied increasing time-out durations may be seen by inspecting the changing probabilities associated with a given interval-class across the frames of figures 9 through 11.

The fact that these probabilities increased most markedly in the early portions of the fixed-interval and that the magnitude of the increase was a function of time-out duration, suggests that the subjects may have been timing from the termination of the preceding reinforcer rather than from the onset of the key-light which marked the beginning of the fixed-interval. However, the present experiments provided no direct test of this rather interesting hypothesis.

Figure 12 presents for each subject response rate measures for all time-out durations investigated. The filled symbols represent response rates following the 8 sec feeder duration while open symbols represent response rates following the 1 sec feeder duration. The circles represent

Figure 12. Response rate measures for each subject as a function of time-out duration. The filled symbols represent response rates following the 8 sec feeder while the open symbols represent response rates following the 1 sec feeder duration. The circles represent running rate and the squares represent overall response rate.

RESPONSES PER MINUTE


B-1
B-2
B-3
AFTER 8 SEC
AFTER 1 SEC
RUNNING RATE
OVERALL RATE
RESPONSES PER MINUTE
TIME-OUT DURATIONS (SEC)
0
10
20
30
40
50
60
70
5
10
20
60
120

running rate and the squares represent overall response rate. Running rate decreased as a function of time-out duration for B-1 and B-2 while remaining fairly constant for B-3. With the possible exception of B-3, running rates did not differ with respect to the preceding feeder duration. The overall rates for B-1 and B-2 were constant despite changes in the mean time to the first response (see Fig. 8). The overall rates for B-3 tended to increase over the first three time-out values and remained constant over the last two time-out values. Although the effect is small, the overall response rates seemed to be more strongly related to the preceding feeder duration than were the running rates. Changes in overall rate here were primarily the result of changes in the mean time to the first response as in previous conditions.

CHAPTER III

DISCUSSION

In Exp. 1 when only one feeder duration was presented within a session feeder duration had no systematic effect on the mean time to the first response or on measures of response rate. In Exp. 2, however, the mean time to the first response was systematically related to the feeder duration which initiated the fixed-interval. The mean time to the first response in Exp. 2 tended to be longer after the longer duration than after the shorter duration with the difference between these means increasing as the value of the shorter duration was decreased over blocks of sessions. Overall response rate was consistently higher following the shorter feeder duration than following the longer duration. Overall response rate following the long feeder duration did not vary across experimental conditions. This finding is surprising from several viewpoints. It may be that the invariance observed reflects a ceiling effect. That is, the strengthening effects are such that they impose a maximum on the length of the pause that can be generated by after-effects.

Overall response rate following the shorter duration, however, increased as the value of the shorter duration was decreased. These rate changes were almost entirely due to changes in the mean time to the first response following the shorter feeder durations. Running response rate was not systematically related to feeder duration in Exp. 2. Both the mean pause data and the overall response rate data support the earlier findings of Staddon (1970a).

The single difference between the findings reported by Staddon and those of the present Exp. 2 was the relationship between feeder duration and running rate. Staddon found both overall and running rates to decrease as the feeder duration which initiated the interval was increased in duration. However, in a study on reinforcement omission Staddon and Innis (1969) have also found running rate to be insensitive to the event which initiates the fixed-interval. Staddon used a fixed-interval 1-min schedule in his investigation of feeder duration effects (1970a) whereas both the present research and the study reported by Staddon and Innis (1969) used a fixed-interval 2-min schedule. Staddon (1970a) has suggested that fixed-interval duration may be an important factor in determining whether running rate will be sensitive

to such manipulations. Thus, the findings of Exp. 2 concur with those reported by Staddon (1970a). These data, however, differ markedly from the data of Exp. 1 in which feeder duration had no systematic effect on the mean time to the first response or on measures of response rate. The question arises as to why the mean time to the first response depends on feeder duration when more than one feeder duration is presented within a session and apparently does not when only one feeder duration is presented within a session.

There are several possible explanations for the difference between the findings of Exp. 1 and those of Exp. 2. One of the possibilities mentioned was that on the mixed schedule the mean latency to the first response was shorter after the shorter duration than after the longer duration because of "run-throughs". The data of Exp. 2, however, indicate that the shorter mean was not the result of averaging a bimodal distribution of latencies to the first response. If this had been the case, the conditional probability curves derived from intervals following the shorter duration should have peaked soon after reinforcement and then overlapped the curve derived from intervals initiated by the 8 sec feeder duration. As can be seen in

figures 4 through 6, this was not the case. The conditional probability of terminating the latency to the first response was higher following the shorter duration than following the longer duration over the entire fixed-interval. This finding suggests that the shorter mean time to the first response following the shorter feeder duration resulted from an effect of the prior feeder duration which lasts over time. Any acceptable explanation of the differences between Exp. 1 and Exp. 2 must, therefore, be one in terms of an effect of the prior feeder duration which lasts over time. Several such views will now be considered.

Time-out periods are frequently conceptualized as intervals during which the effect of some antecedent stimulus event dissipates with the passage of time. Hence, when the experimental objective is to prevent the effect of one stimulus from interacting with the effect of a subsequent stimulus presentation, a time-out may be interpolated between the two stimulus events. For example, McKinnon and Amsel (1964) have reported that as detention time (time-out) following a frustrative event is increased the frustration effect is attenuated and eventually eliminated.

The findings of phase 1 of Exp. 2 are consistent with the frustration theory proposed by Amsel (1958, 1967). Moreover, these data are consistent with Bower's (1962) report that the magnitude of the frustration effect is related to the amount of reduction in reward. As can be seen in Figure 3 the mean time to the first response was shorter following the shorter duration than following the longer duration in every case. Also, the mean time to the first response following the shorter feeder duration decreased as the value of the shorter duration was decreased. Since overall response rate varied largely as a result of decreases in the mean time to the first response the data of Figure 4 are also compatible with the theory. Running rate was not systematically related to feeder duration. This may be related, as Staddon has noted (1970a), to instances in the runway literature where the frustration effect results largely from changes in "start time", a measure similar to the latency to the first response measure used here. The mean time to the first response was longer following the 8-sec feeder when two feeder durations were presented within a session (Exp. 2) than when only the 8-sec feeder duration was presented within a session (Exp. 1).

Frustration theory, however, would predict that the latency to the first response following the 8-sec feeder duration in Exp. 2 would not have been substantially different from that observed in Exp. 1. With this exception, the data obtained in phase 1 of Exp. 2 correspond with the theoretical predictions of frustration theory. The theory would predict the data of Exp. 1 in the following way. Since feeder duration was not varied within sessions in Exp. 1 the duration to which the subject received always corresponded to the duration to which it was accustomed to obtaining. In Exp. 1, therefore, there were no "reduced" amounts of reward and the frustration effect was not observed due to the absence of one of its pre-conditions.

If the shorter pauses following the shorter feeder durations observed in phase 1 resulted from exposure to frustrative stimulus events then the time-out manipulations of phase 2 should have allowed the frustration effect to dissipate over time. Thus, increased time-out durations should have eliminated any differential pausing due to frustration. The manipulations did in fact eliminate differential pausing but they did so by increasing the tendency to respond early in the fixed-interval following

both the long and short feeder durations. The mean pause following both feeder durations systematically decreased as time-out duration was increased. Unless it is assumed that the time-out is itself a frustrative stimulus event these data are in direct opposition to the predictions of frustration theory which would predict a gradual lengthening of pauses following the shorter feeder duration until these pauses were not significantly different from those following the longer feeder duration.

The data obtained in phase 1 of Exp. 2 are also consistent with the overshadowing hypothesis (Staddon, 1972). The mean time to the first response was shorter following the shorter duration than following the longer duration under all conditions. The observation that pauses following the shorter duration tended to increase as the value of the shorter duration was increased lends support to the notion that overshadowing becomes less probable as the less-valued stimulus is increased in duration. Whereas the observed changes in overall response rate may be attributed to changes in the mean pause duration the finding that overall response rate in fixed-intervals initiated by a short feeder duration increased as the value of the shorter feeder

duration was decreased is also consistent with this view. Since by the present account the differential after-effects of the various feeder durations are context dependent, the data of Exp. 1 are also consistent with the overshadowing hypothesis.

Since overshadowing is dependent on the intermixing in time of different feeder durations it would be expected that the separation of successive fixed-intervals in time by time-outs of increasing duration should attenuate any effect the overshadowing mechanism might have on performance. If the shorter pauses following the shorter feeder durations observed in phase 1 of Exp. 2 were in fact due to overshadowing then differential pausing should not occur when the mechanism ceases to affect performance. Moreover, there is no reason provided by the overshadowing hypothesis why the mean time to the first response in phase 2 should have differed from that observed in Exp. 1. That is to say, there is nothing in the proposal which can account for the observation that the tendency to respond early in the fixed-interval increased following both feeder durations as time-out duration increased.

Finally, the data obtained in phase 1 of Exp. 2 also support the notion that the differential pausing observed was the result of a shift from a short feeder duration to a relatively longer average feeder duration or vice versa. The fact that the latency to the first response decreased systematically as the shorter feeder duration was decreased in value provides substantial support for this view. As the shorter feeder duration was decreased in value the average duration became relatively longer. Hence, the concomitant decrease in the mean time to the first response is exactly what would be expected if the differential pausing were the result of a reinforcement-context-contrast effect. The data of Exp. 1 are also consistent with this account since such a mechanism can not possibly operate when only a single feeder duration is presented within a session.

If time-out is a period during which the effects of previously presented stimuli dissipate then the after-effects of both the short and long feeder durations should diminish as time-out duration is increased. This should work against any reinforcement-context-contrast effect and result in pauses typical of context-free situations. That is, pauses following a short feeder duration should lengthen and not be

significantly different from those following a longer feeder duration. Thus, this view does not predict the increased tendency to respond following both feeder durations which was observed in phase 2 of Exp. 2.

Perhaps conceptualizing the time-out as merely a period during which after-effects of stimuli dissipate is inappropriate. It may be the case that time time-out itself is an important determiner of performance. Support for this notion comes from the data of sessions in which the feeder duration was held constant at 4 sec and successive fixed-intervals were separated in time by a 120 sec time-out. When feeder duration is held constant within a session none of the context dependent effects discussed above should occur. The fact that the tendency to respond was nonetheless very high early in the fixed-intervals suggest that the time-out may have been modulating the after-effects of stimuli and not simply allowing them to dissipate with the passage of time.

There are several possible explanations for the data generated by the time-out manipulations. First, the after-effect may be one which deteriorates over time. If this were the case, one would expect strong effects immediately

after reinforcement with the probability of a response increasing as a result of the deterioration of the effect in concert with changes in other variables which determine the mean time to the first response. Thus, when a time-out is interpolated after every reinforcer the probability of a response early in the interval should increase as time-out duration increases. This is so because the effect would begin to deteriorate whether or not the next fixed-interval had been initiated. Several considerations, however, indicate that it would be necessary to assume that the effect deteriorates with respect to relative time. For example, consider an event which, on a fixed-interval 2 min schedule, results in a mean time to the first response which corresponds to a relative proximity value of 0.50. If the effect deteriorated with respect to absolute time the same event, when presented on a fixed-interval 4 min schedule would result in a mean pause duration which corresponded to a relative proximity value of 0.25. This prediction is at odds with the findings of several investigators (Schneider, 1969; Shull, 1971) that the mean pause duration on fixed-intervals is related linearly to the fixed-interval duration. That is, regardless of the fixed-interval value the mean time

to the first response approximates a relative proximity value of 0.50. Thus, the rather unusual assumption that the effect deteriorates with respect to relative time must be made if the foregoing account is to have any generality at all. In addition there remains the problem that such after-effects are context dependent and thus can not deal with data from sessions in which only a single feeder duration was presented. There are, then, a number of problems for this account.

An alternative explanation is that the context dependent contrast effect results in differential after-effects which persist over time. These differential after-effects interact with the schedule in such a way that at very high relative proximity values differential pausing is not likely to be observed due to the overall increase in the tendency to respond. At low relative proximity values, however, differential pausing should be clearly evidenced. The time-out manipulations had the effect of progressively altering the relative proximity associated with a given point within the fixed-interval by changing the inter-reinforcement interval. At a time-out value of 120 sec, for example, the beginning of the fixed-interval corresponded to a relative proximity value of 0.50. The increased tendency to respond

early in the fixed-interval may have been the result of a larger proportion of key-pecks due to the stimulus-reinforcer relationship as distinguished from key-pecks due to the response-reinforcer relationship. In a study of auto-maintenance of the pigeon's key-peck Groves (1973) has found that as the relative proximity value associated with the onset of a trial is increased there is a concomitant increase in the number of pecks observed. Under the usual fixed-interval procedure the relative proximity value associated with the beginning of the interval is zero. Hence, very few pecks due to stimulus-reinforcer relationships would be expected. Interpolating a time-out after each fixed-interval, however, should yield a larger number of such key-pecks. Thus, as time-out duration was increased responses early in the fixed-interval became more probable because these times were now associated with higher and higher relative proximity values. This would account for the finding that differential pausing was eliminated as a result of an increased probability of terminating the latency to the first response at times early in the interval following both feeder durations with the effect occuring more rapidly in intervals following the short feeder durations. Thus, it is

not the after-effect of the event *per se* which is changed but rather the behavioral situation with which the event must interact. While this account apparently deals with all of the data generated by the present research, independent testing of its assumptions awaits further research.

CHAPTER IV

SUMMARY

Previous investigations have suggested that the mean time to the first response on fixed-interval schedules depends on feeder duration. The present research found that when only one feeder duration is presented within a session the mean time to the first response does not depend on feeder duration. When more than one duration is presented within a session however, the mean time to the first response decreases as the feeder duration which initiates the interval is decreased. It was also found that the interpolation of a time-out between successive fixed-intervals results in an increased tendency to respond early in the interval as time-out duration is increased. Frustration theory, the over-shadowing hypothesis (Staddon, 1972), and the reinforcement-context-contrast effect were all discussed as possible explanations of the data generated by the present series of experiments. The increased tendency to respond early in the fixed-interval when a time-out is interpolated between successive intervals may be the result of a proportionally larger number of pecks occuring as a result of stimulus-reinforcer relationships.

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